Status of field maps

Science Board Meeting

9 / 11 / 2016

Laura Zambelli for the LAPP group

Progress since last SB

- Study of diffusion coefficient parametrization as a function of E

- Clean up and improve the Efield map generation macro

- Cross check of new comsol results produced by Hasegawa-san (6x6x6 and 3x1x1)

Diffusion coefficient parametrization

$$D = kT \times \mu = \varepsilon\mu$$

where **ε** is the electron energy
μ is the electron mobility, **μ**=v/E

<u>At 0 field :</u>
the electron is in equilibrium with the LAr : **ε**(E=0) ≃ 0.0075 eV
the mobility reach a constant : **μ**(E=0) ≃ 518 cm2/(Vs) [electron mobility is not divergent!]

→ D(E=0) ≃ 3.88 cm2/s for longitudinal and transverse diffusions

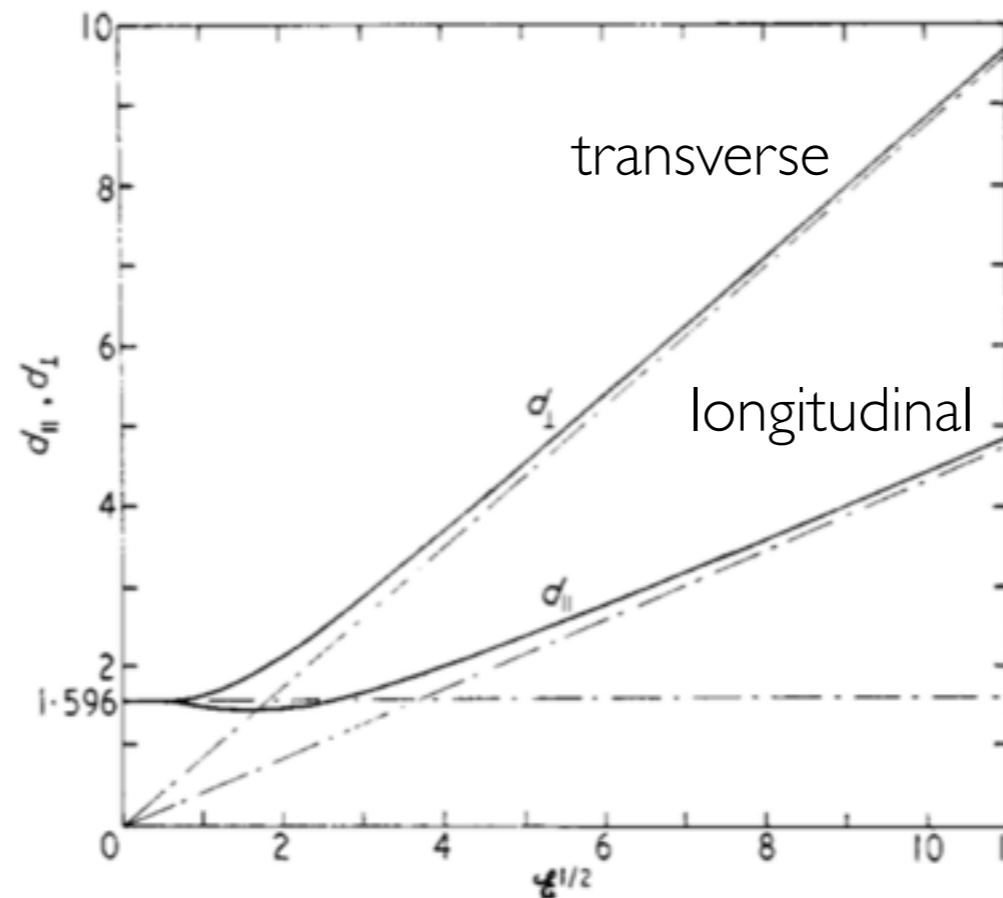H Skullerud, J. Phys. B**2** 696 (1969) :

Figure 1. The dimensionless diffusion coefficients $d_{\parallel} = ND_{\parallel}\sigma_M(kT/m)^{-1/2}$ and $d_{\perp} = ND_{\perp}\sigma_M(kT/m)^{-1/2}$ as functions of the dimensionless field parameter $\mathcal{E} = (E/N)(e/kT\sigma_M)(M/m)^{1/2}$. Asymptotic values for large and small $\mathcal{E}$ are shown as broken lines.

Diffusion coefficient parametrization

H Skullerud, J. Phys. B**2** 696 (1969) :

The physical reason for the difference between the longitudinal and the lateral diffusion coefficients can be outlined as follows:

Let us consider the case of a collision frequency $\nu_M(v)$ *increasing* with the velocity. An electron diffusing against the **a** direction will lose energy, and thus acquire a lower velocity, a lower collision frequency and an increased instantaneous drift velocity, which after some time (of the order $\tau_e = \tau_M(v)/\xi$) will have reduced the distance which the electron lagged behind the average electron position. Similarly an electron diffusing in the **a** direction will gain energy, and acquire a lower instantaneous drift velocity. The longitudinal spread of a group of electrons will thus be diminished compared with the lateral spread due to a 'drift-phase-stabilization' mechanism.

We shall consider then the case of a collision frequency $\nu(v)$ *decreasing* with increasing velocity. In this case an electron which has diffused against the **a** direction will have a lower instantaneous drift velocity, and an electron which has diffused in the **a** direction has an increased instantaneous drift velocity. The longitudinal spread of a group of electrons will thus be enhanced compared with the lateral spread.

As the field increase, the velocity increase (and mobility decrease),
the electron gain energy from collisions in the Argon. Experimentally it has been measured than transverse diffusion is larger than longitudinal → we are in the case where the collision frequency increase with the velocity.

Diffusion coefficient parametrization

R. E Robson, Australian Journal of Physics **25** (1972) 685 :

(here K is the mobility, W the drift velocity)

where

$$D_{\mathrm{T}} = (kT/e)K \qquad \text{and} \qquad D_{\mathrm{L}} = (kT/e)(K + E\,\partial K/\partial E) \qquad (11\mathrm{a,b})$$

denote the transverse and longitudinal diffusion coefficients respectively. The ratio of diffusion coefficients parallel and perpendicular to the field is therefore

$$D_{\mathrm{L}}/D_{\mathrm{T}} = \partial(\ln W)/\partial(\ln E), \qquad (12)$$

where

$$W \equiv KE \qquad (13)$$

is the average velocity under spatially uniform conditions. The latter quantity is conventionally referred to simply as the drift velocity of the swarm.

Here a parametrization of D as a function of E is proposed.
But it is not clear what is (kT) representing:
   - Global electron energy ?
   - Transverse electron energy ? ← what I've assumed

And equation (12) could be written as:

$$\frac{D_L}{D_T} = 1 + \frac{E}{\mu}\frac{d\mu}{dE}$$

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Diffusion coefficient parametrization

Li et al NIM A 816 (2016) 160–170 [1508.07059] :

- Measured electron drift velocity and longitudinal diffusion in liquid and gas argon
- E field vary from ~100 V/cm to ~4 kV/cm
- Parametrized the mobility and electron longitudinal energy as a function of E with polynomials

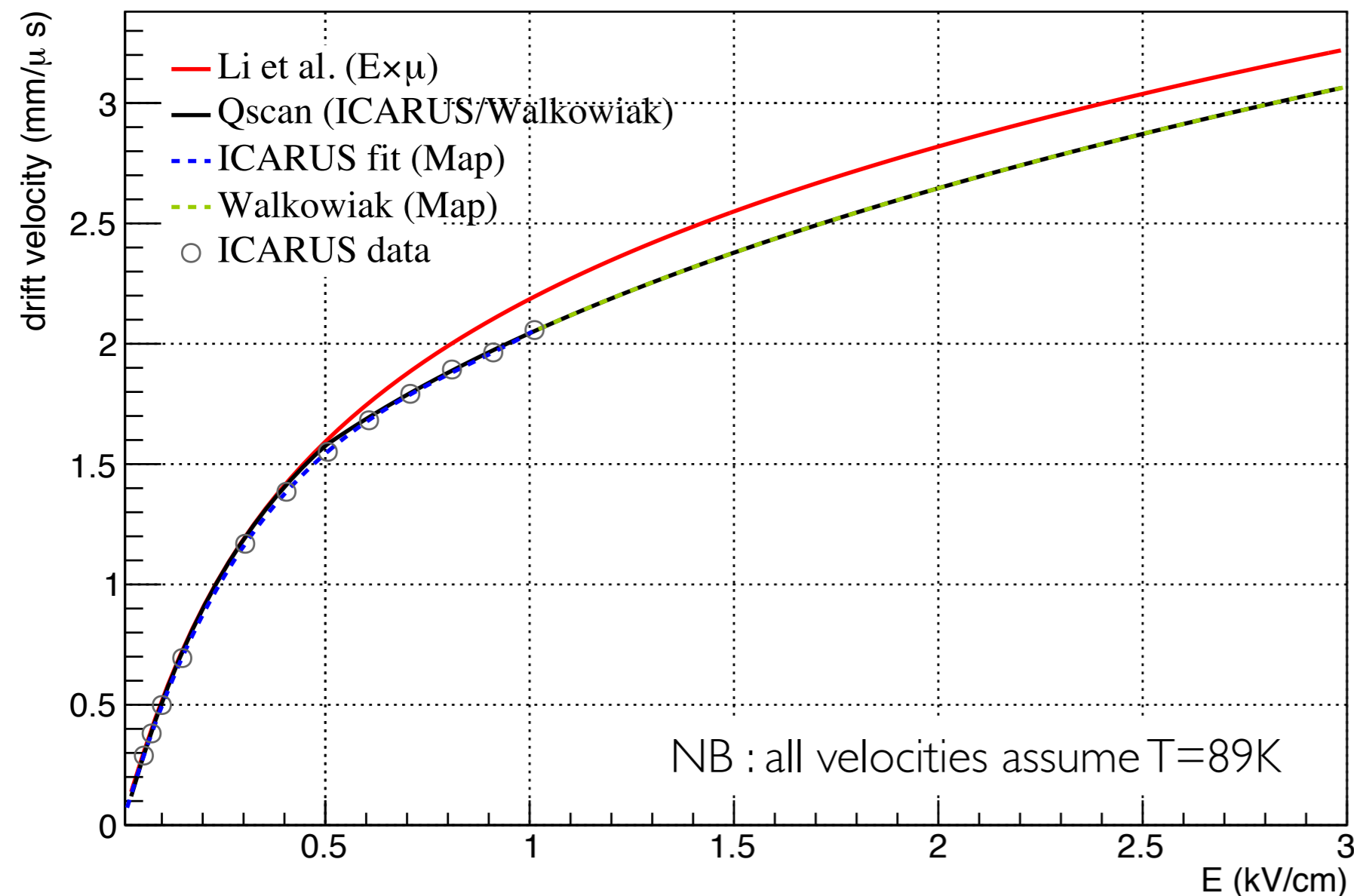E/N is the reduced electric field (/density) [1 Td = 1e-17 V cm^{-2}]
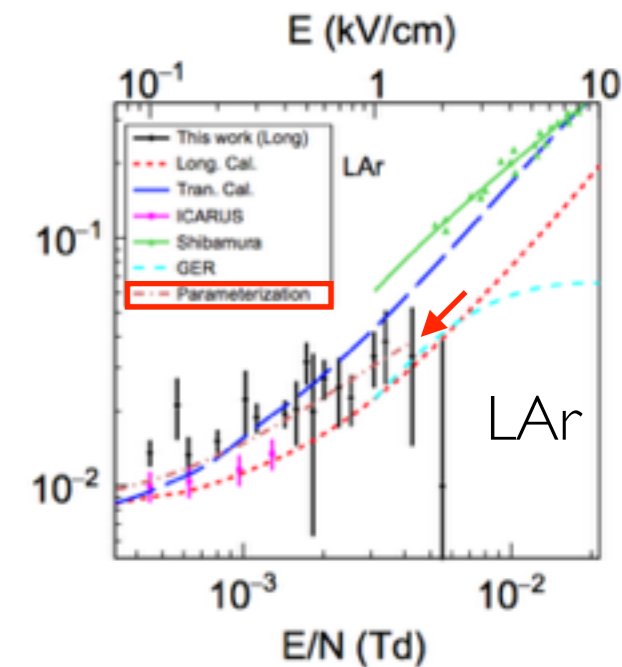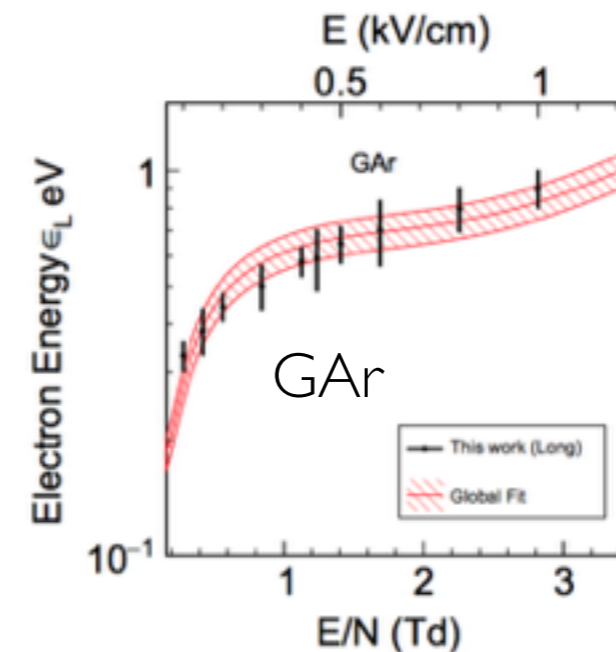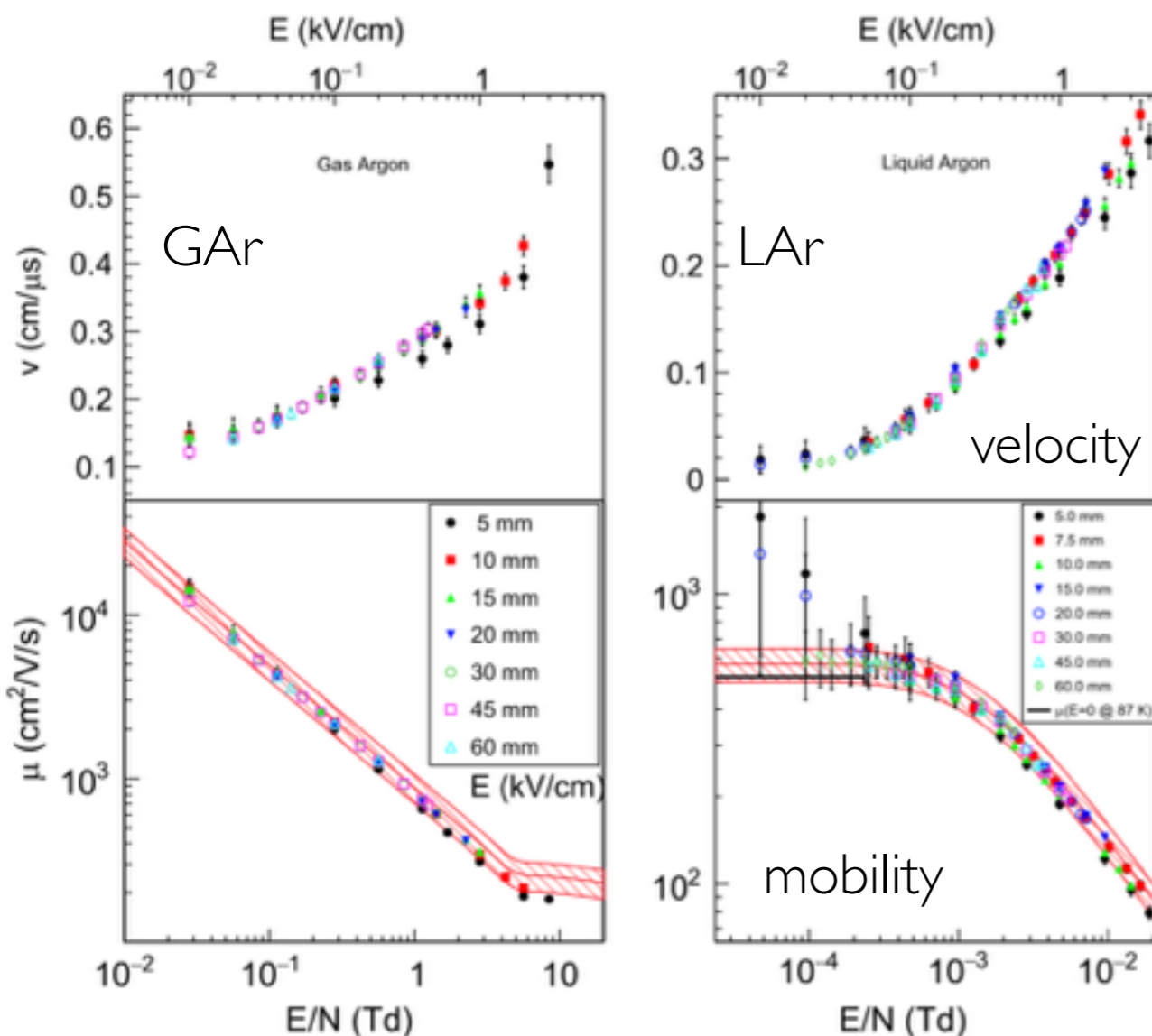
Diffusion coefficient parametrization

Given the formulas :

$$D_L = \varepsilon_L \mu$$

$$\frac{D_L}{D_T} = 1 + \frac{E}{\mu}\frac{d\mu}{dE}$$

And the parametrization of εL and μ
→ we can parametrize Dt and Dl

Problem : our velocity parametrization isn't the same as the Li one (in particular for E > 0.5 kV/cm)
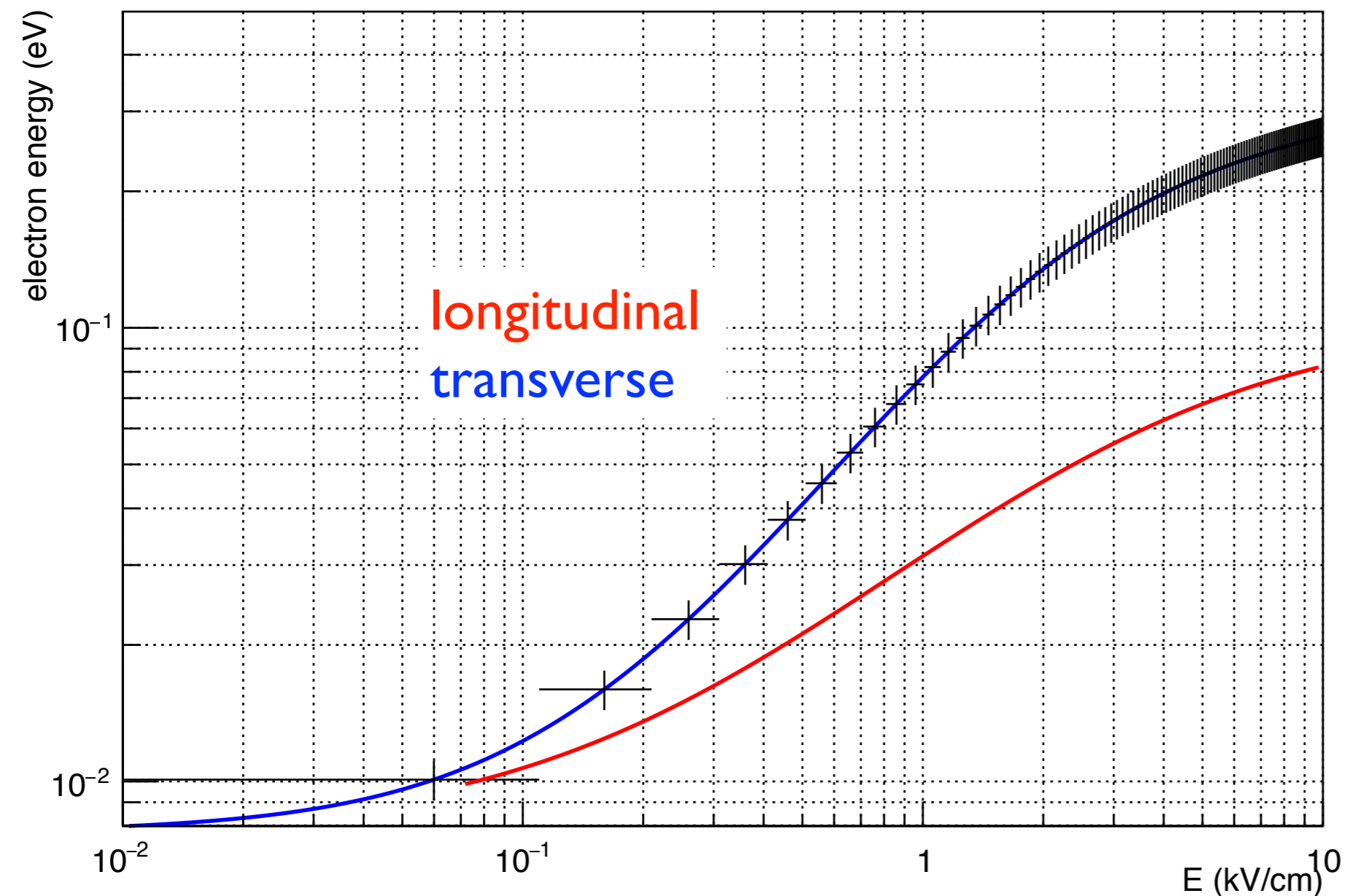
Diffusion coefficient parametrization

Define our mobility parametrization as v/E but ensure the non-divergence at low field

Li et al

v(QScan)/E

v(QScan)/E non divergent
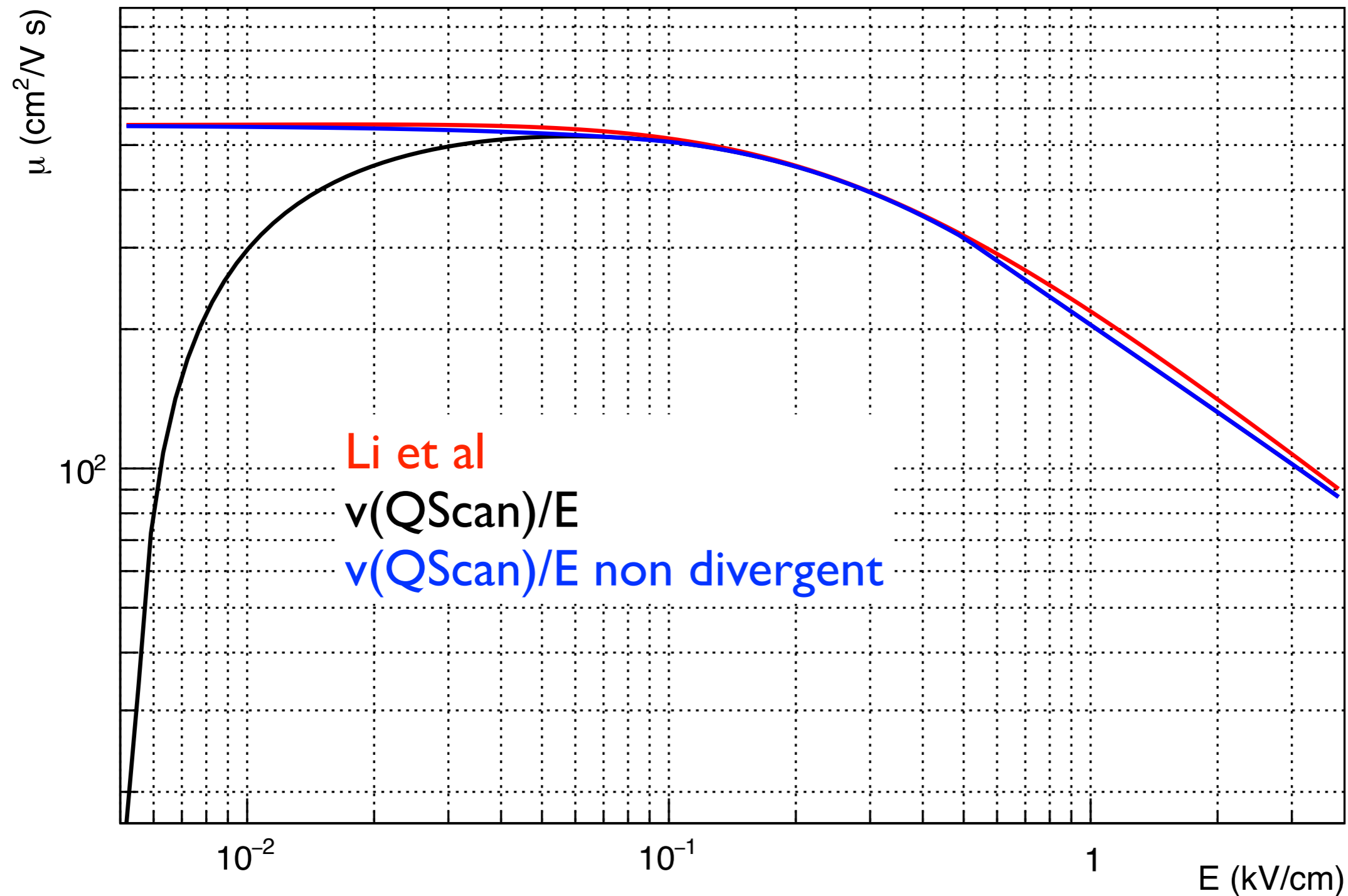
Diffusion coefficient parametrization

And retrieve **ε**T by playing with the formulas :

$$\varepsilon_T = \frac{1}{\mu} \frac{D_L}{1 + \frac{E}{\mu} \frac{d\mu}{dE}}$$

Assume 10% error on 'data' points for the fit as in the paper

Diffusion coefficient parametrization

Dotted line : this parametrization
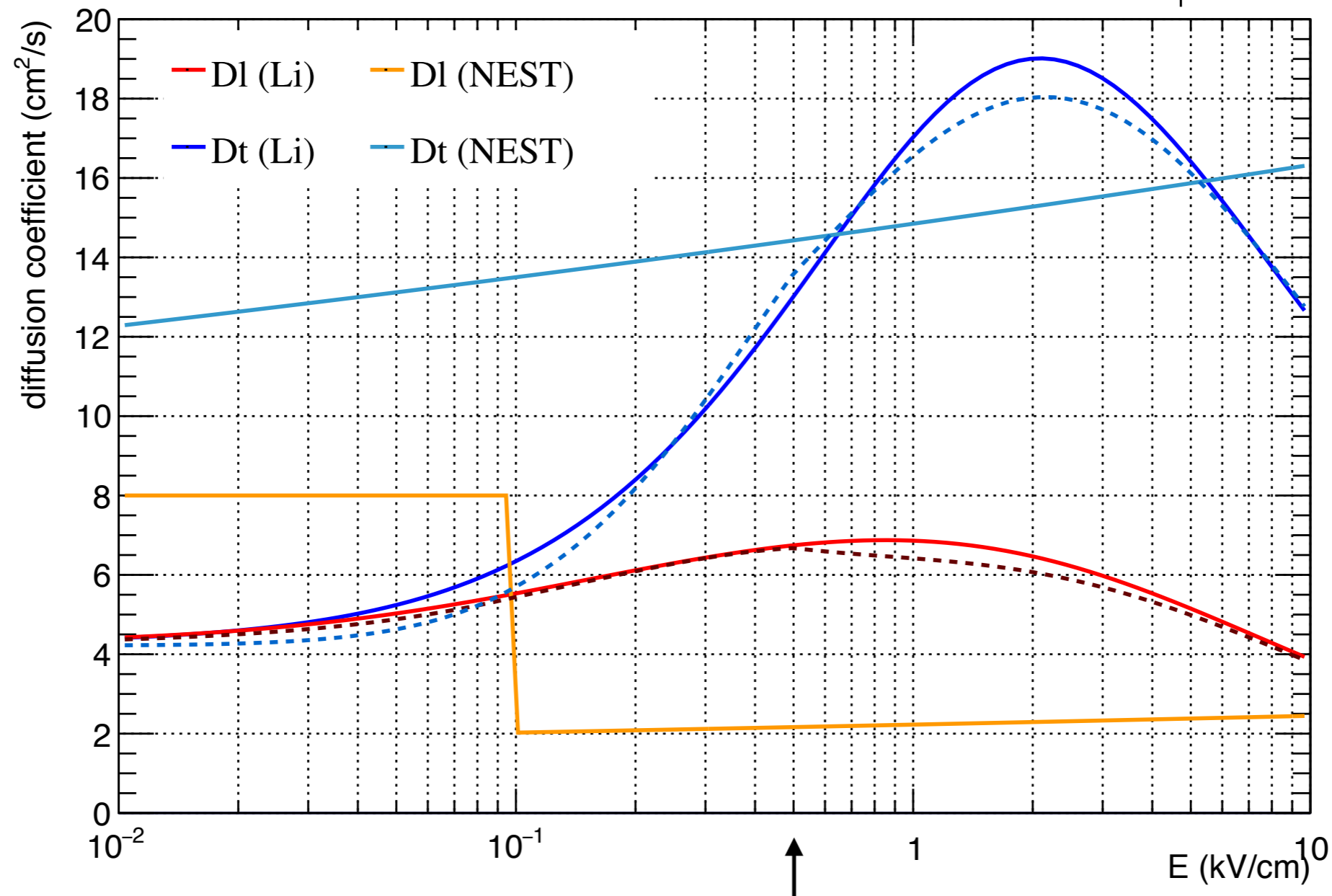
in QScan where we switch from icarus fit to walkowiak function
- Breaking point at 100 V/cm for Dl with NEST
- Difference between Li and this parametrization is due to a different drift velocity parametrization
- Dl and Dt converges at low field

at 0.5 kV/cm: DL = 6.7 cm2/s DT = 13.6 cm2/s
at 1 kVcm: DL = 6.4 cm2/s DT = 16.6 cm2/s
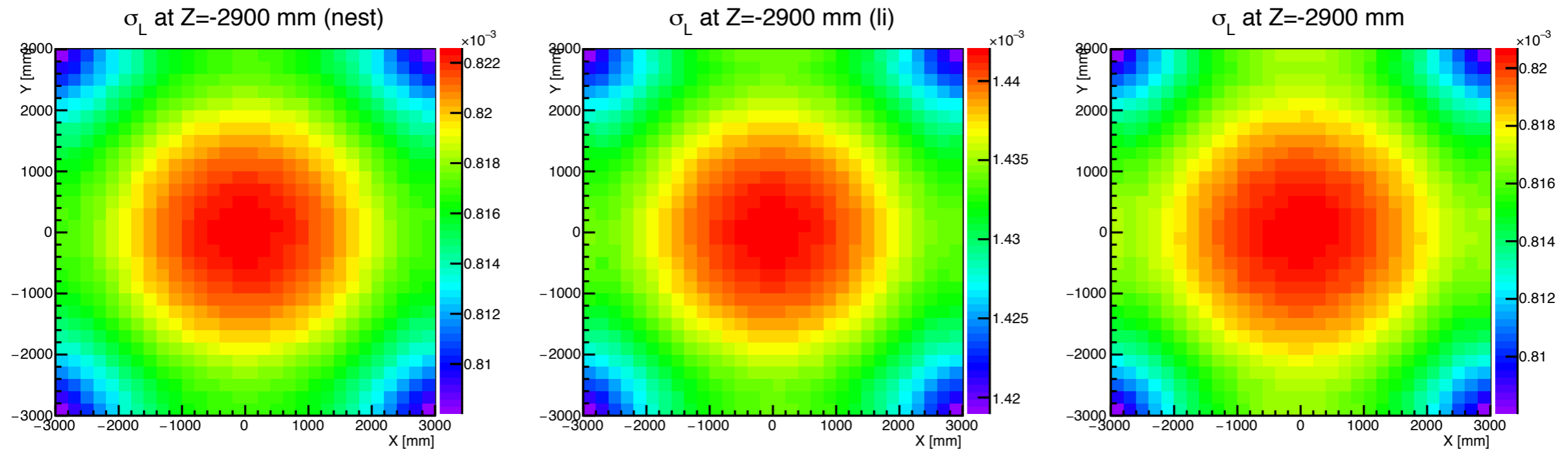
Diffusion coefficient parametrization

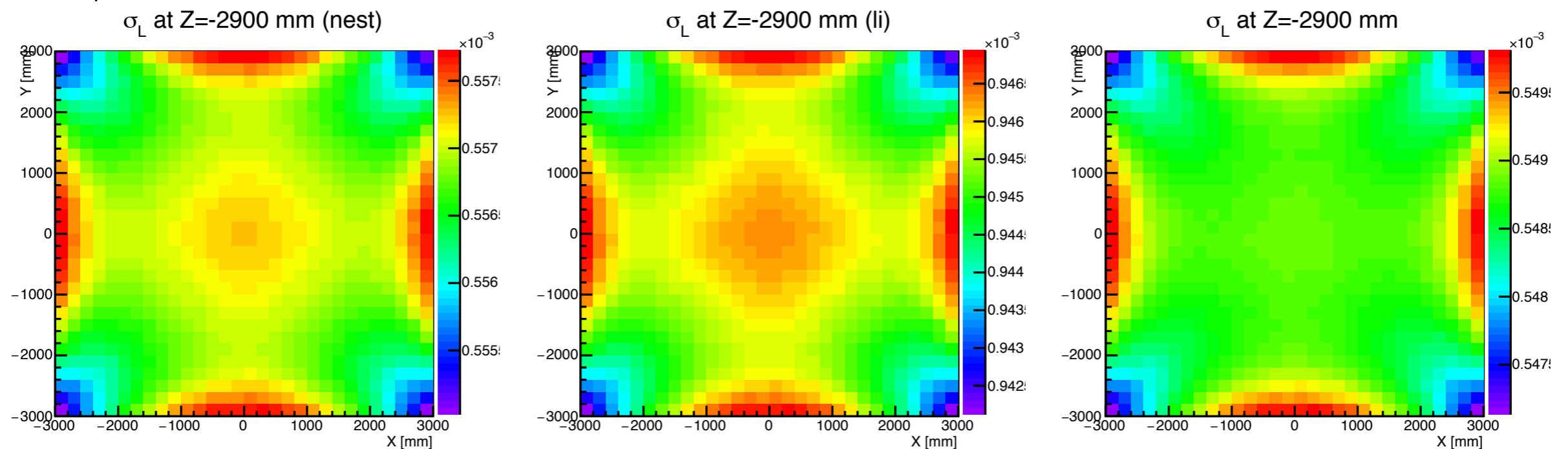Dotted line : this parametrization   zoom in our fields of interests
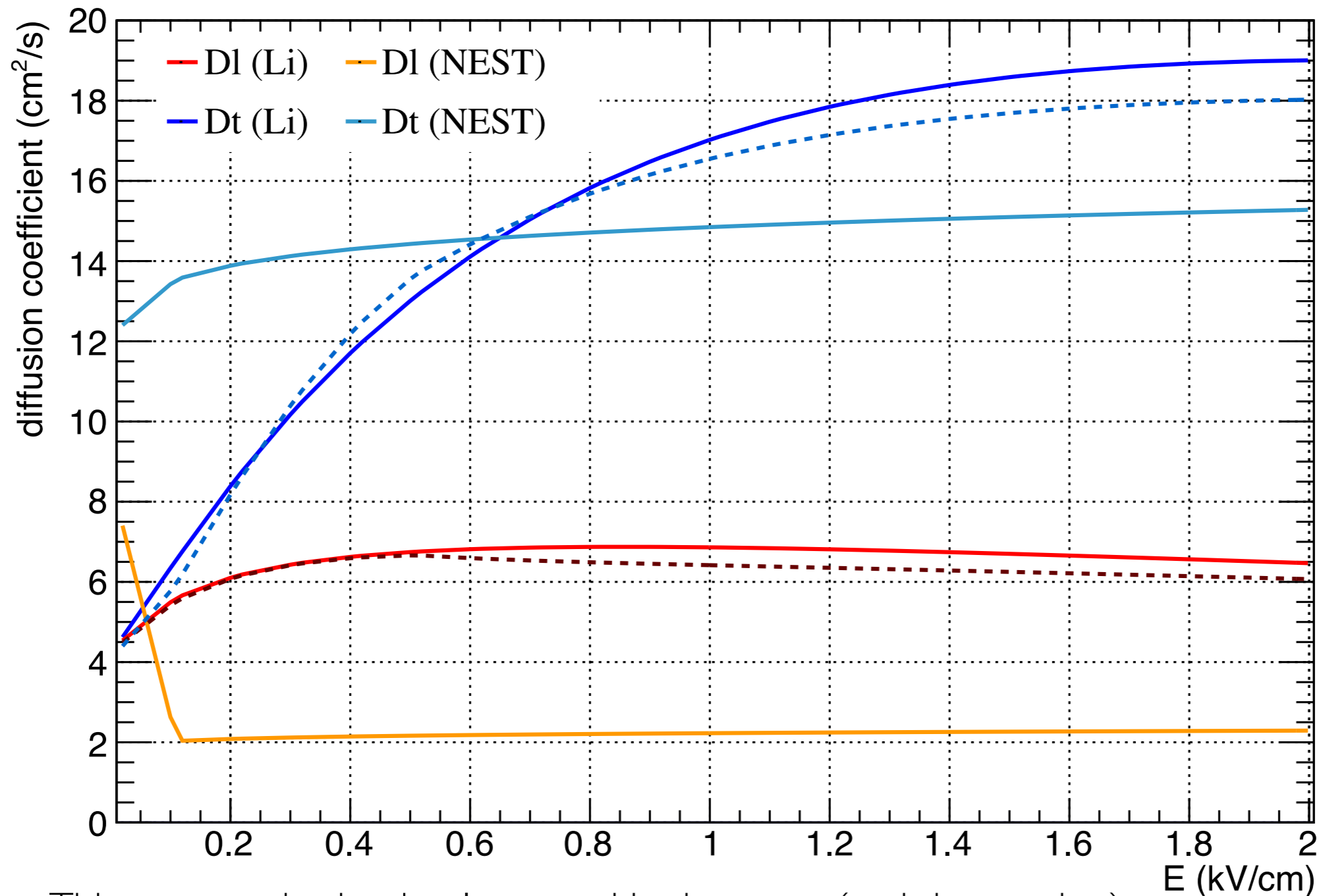
→ This parametrization implemented in the maps (path integration)
→ Kept NEST to compare (path integration)
→ Also kept the non-path integration version (using NEST values for DL and DT)

Diffusion in maps - longitudinal
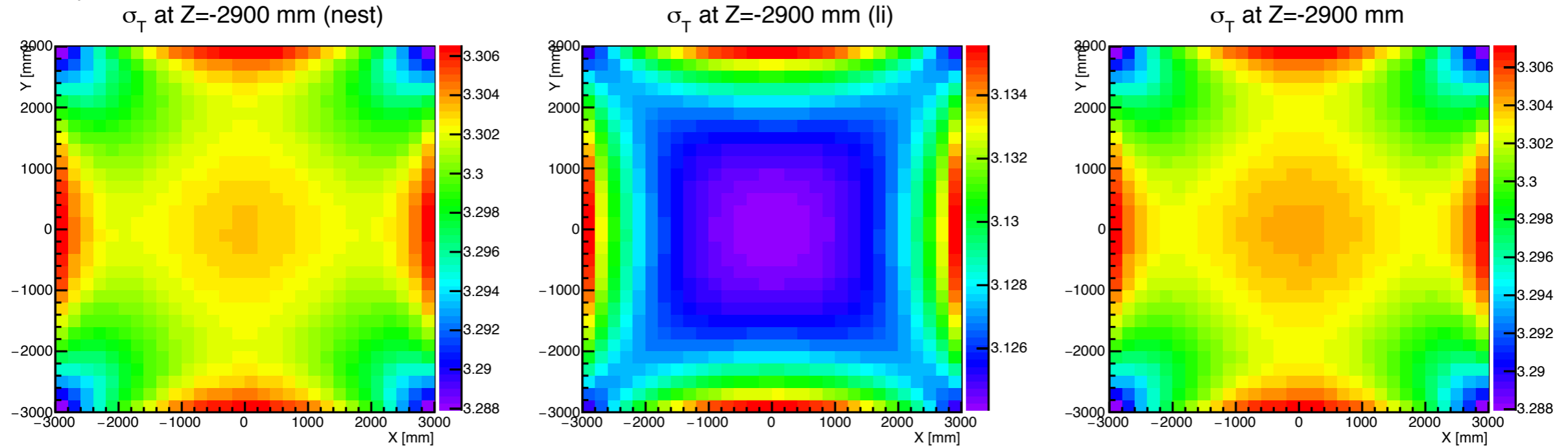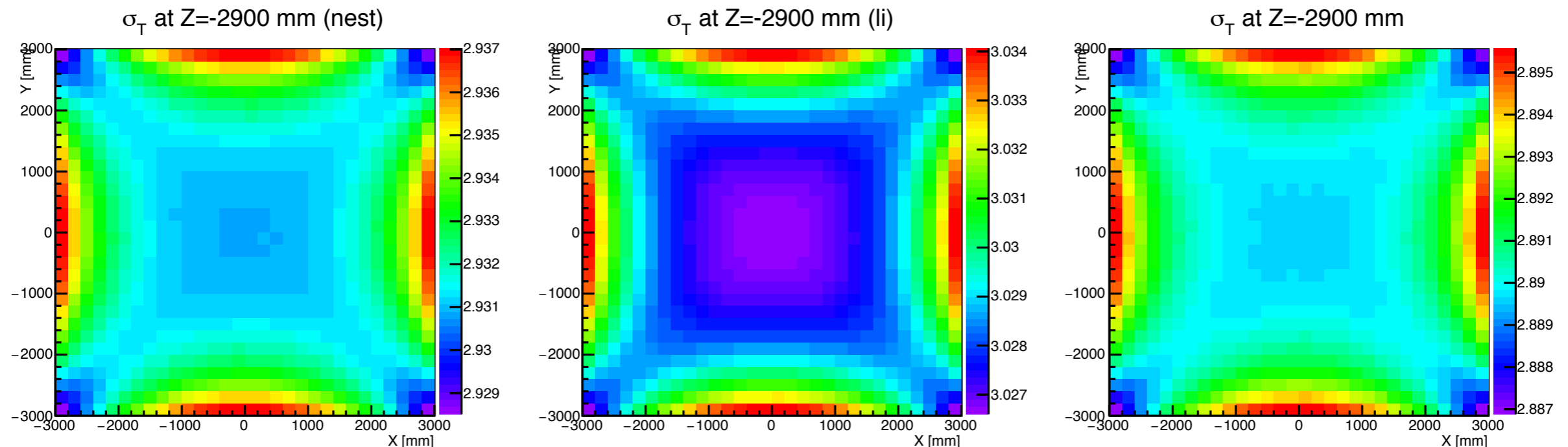
666 maps, no IBF:

666 maps, 10% IBF:

DL (li) > DL (NEST) and DL vary a little with E → no major difference, maps varies like the drift time

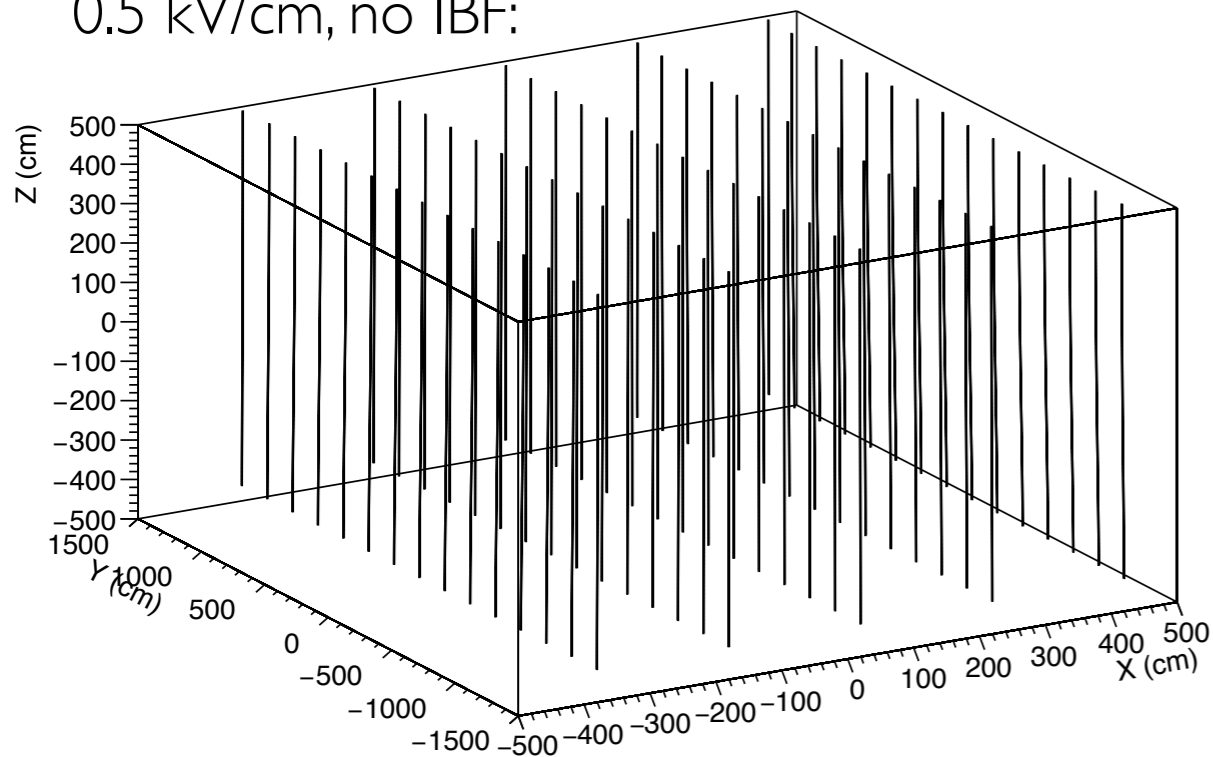# Diffusion in maps- transverse

666 maps, no IBF:

666 maps, 10% IBF:

DT (li) ≃ DT (NEST) but DT(li) vary a lot with E → σT(li) varies like the E

DT(NEST) is ~constant with E → σT(NEST) varies like the drift time
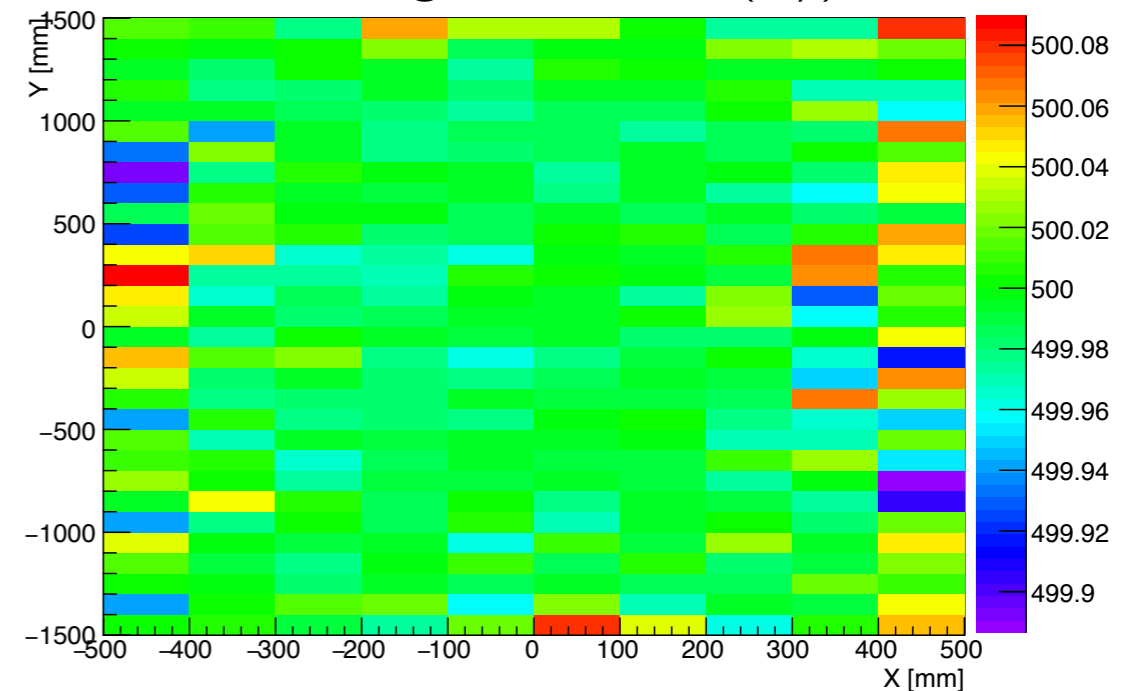
E-Field maps for 3x1x1

Lines are the drifted electron trajectories when produced at the bottom of the detector
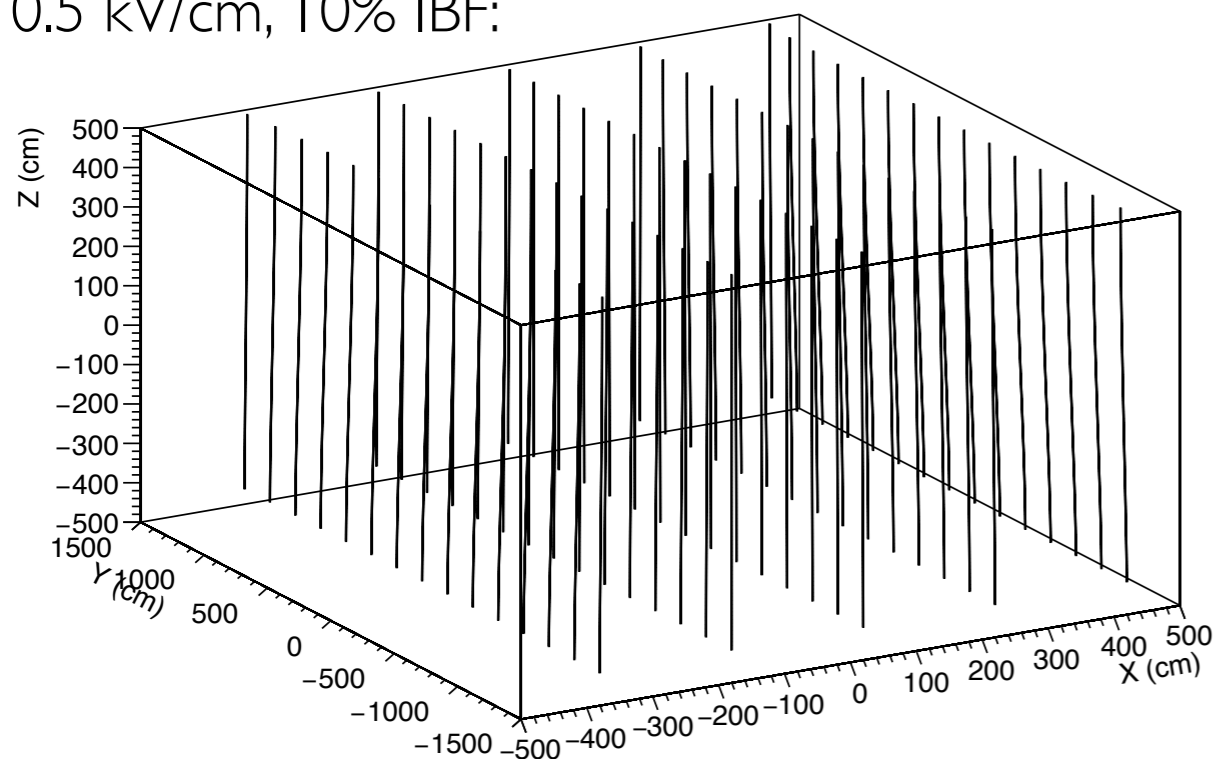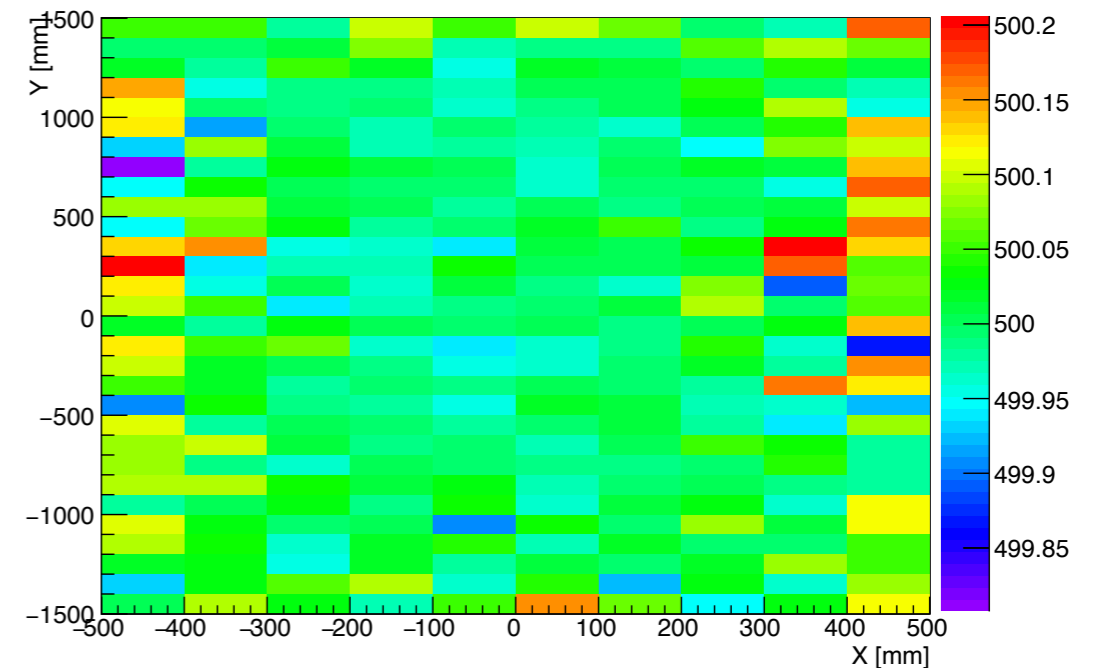
0.5 kV/cm, no IBF:

Average E-Field in (x,y)

0.5 kV/cm, 10% IBF:

Average E-Field in (x,y)

Prospects

- I propose to switch to the modified Ii parametrization for the diffusion
    - Will update accordingly QScan for consistency

- I've checked the map production code for possible bugs, now it's ready for commit !
    - Consistent velocity treatment, consistent LAr temperature

- 3x1x1 maps seems ok to me, will now look at their effects in a simulation